On the charge of the photon

L.B. Okun
ITEP, Moscow, 117218, Russia

Abstract

The papers setting upper bounds on the value of electric charge of the photon are briefly reviewed. The theoretical framework of these bounds is shown to be incomplete. Hence the bounds seem to be unreliable.

There exists about a dozen of papers questioning the neutrality of photon and setting an upper limit on its charge. The title of the first paper [1] was "Experimental limit on the "charge" of the photon". Please note that the word "charge" was in quotation marks, which, I suspect, reflected the scepticism of the authors. They searched for the effect of electric field $V = 20$ kv on the energy of 14.4 KeV photons emitted by Fe^{57} and investigated with the use of recoilless resonance scattering. Neither an energy shift nor a line broadening has been observed allowing the authors to set the limit $e_\gamma/e < 10^{-15}$.

The authors of experiment [2] were searching for small charge ($\lesssim 0.1e$) of a Millikan type spheroid suspended magnetically and exposed to electric field. In this experiment the light used in the suspension system (photons of average energy 2 eV) for duration of at least 8 hours would increase the charge of spheroid if photons were charged. Non-observation of any effect led the authors to an estimate $e_\gamma/e < 10^{-16}$. This result was a by-product of experiment looking for free quarks and was briefly described in the last paragraph of the article [2].

The latest limit $e_\gamma/e < 5 \cdot 10^{-30}$ given by "Review of Particle Physics" [3] is based on the idea of the absence of anomalous spread of photons arrival time, applied to the radio pulses from millisecond pulsar PSR/1937+21. The idea was put forward in 1988 by Cocconi [4], who obtained $e_\gamma/e < 2 \cdot 10^{-32}$. In 1994 Raffelt [5] noted that Cocconi had not taken into account the standard

dispertion effect in the interstellar plasma. By including this effect Raffelt [5] concluded with $e_\gamma/e < 5 \cdot 10^{-30}$.

A somewhat weaker constraint was derived in 1992 by Cocconi [6] from the angular spread of photons propagating from distant compact extragalactic sources: $e_\gamma/e < 2 \cdot 10^{-28}$. In 2004 Kobyshev and Popov [7] suggested that in this way the limit could be improved to $e_\gamma/e < 3 \cdot 10^{-33}$.

Limits on e_γ/e based on isotropy of the cosmic microwave background radiation and some additional assumptions were proposed in 1994 by Sivaram [8] and in 2005 by Caprini et al. [9].

The recent laboratory measurement of the deflection of a laser beam in a modulated magnetic field has allowed to Semertzidis, Danby, and Lazarus [10] to produce an upper limit $e_\gamma/e < 8.5 \cdot 10^{-17}$, which is at the level of experiments [1] and [2].

With such a diversity of phenomenological approaches all articles listed above have one common feature: they ignore the basic changes in quantum electrodynamics which are needed to include the non-vanishing charge of the photon.

First of all, if photon is charged and principles of Quantum Field Theory are not violated, then there should exist at least two kinds of photons with opposite signs of charges. A minimal Yang-Mills type theory requires also a neutral photon and SU(2)-symmetry. This calls for SU(2)-multiplets of electrons, muons, τ-leptons, as well as quarks. Such extra degeneracy seems to be in contradiction with totality of data on atomic, nuclear and particle physics.

Note that the minuscule value of the photon electric charge does not soften the problem of degeneracy.

I have asked one of the authors of refs. [1] - [10], whether he thinks that a selfconsistent scheme with a charged photon exists or could be invented. His answer was: "I have never heard of a consistent theory with a charged photon. However, theory aside, it is important to test our preconceptions, I suppose".

I replied: "But you are testing it in a framework of a "theory"."

The point is that the interaction of a charged photon with magnetic or electric field is described by a vertex with three photonic lines. If there exists only one kind of photons, say, with charge $+e_\gamma$, but not $-e_\gamma$, then such a vertex would violate charge conservation. Moreover the static fields containing many virtual photons would be macroscopically charged.

Note that if charge is conserved, then in the case of a single charged

photon the vertex with three photons is forbidden and formulas used to calculate the deflection of photons in magnetic field are invalid.

Note also that emission of each new photon by an electron would change the charge of the latter. Hence an infinite number of different kinds of electrons are needed.

The situation is not so desperate in the case of a triplet of photons. But it calls for a more comprehensive analysis.

I am grateful to A. Buras, V. Fadin, M. Krawczyk, and P. Zerwas for drawing my attention to the putative charge of the photon.

References

[1] L. Grodzins, D. Engelberg, and W. Bertozzi, Bull. Am. Phys. Soc. **6** (1961) 63.

[2] R.W. Stover, T.I. Moran, and J.W. Trischka, Phys. Rev. **164** (1967) 1599.

[3] Particle Data Group "Review of Particle Physics", Phys. Lett. B **592** (2004) 31, 335.

[4] G. Cocconi, Phys. Lett. B **206** (1988) 705.

[5] G.Raffelt, Phys. Rev. D **50** (1994) 7729; hep-ph/9409461.

[6] G. Cocconi, Am. J. Phys. **60** (1992) 750.

[7] V.V. Kobyshev and S.B. Popov, hep-ph/0411398.

[8] C. Sivaram, Am. J. Phys. **63** (1994) 1473.

[9] C. Caprini and P.G. Ferreira, hep-ph/0310066, JCAP 0502 (2005) 006.

[10] Y.K. Semertzidis, G.T. Danby, and D.M. Lazarus, Phys. Rev. D **67** (2003) 017701.